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EFFECT OF CHEMICAL ADDITIVES ON THE SPREADING QUALITY OF BUTTER. II. LABORATORY AND PLANT CHURNINGS [1]

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SUMMARY

To determine the effect of additives on the spreadability and hardness of butter, 37 materials were added singly or in combination to the cream or to the butter in concentrations of 0.5 to 6%. The materials investigated in 280 laboratory churnings and 42 commercial conventional and continuous churnings included glyceride preparations, Tweens and Spans, stabilizers, vegetable oils, crystal inhibitors, salts, enzymes, detergents, skimmilk solids, and buttermilk solids.

The results revealed that several materials, particularly certain glyceride preparations and Tweens and Spans, lecithin, buttermilk solids, and skimmilk solids were effective in improving the spreadability and decreasing the hardness of the butter. When these materials were added to conventionally churned butter, the spreadability of the butter was improved by 10 to 44% and the hardness decreased from 3 to 21%. In some cases, combinations of additives yielded more effective results than the individual additives added to the same butter. Storage of butter tended to overcome the beneficial effects of the additives indicating that the additive materials may delay but not prevent the normal setting phenomena in butter.

Problems encountered with the additives were difficulty of incorporation into butter and off-flavors at concentrations greater than 1%. However, the additives did not appear to affect the keeping quality nor alter the chemical nature of the butter.

The wide variation in the spreadability of butter continues to be a problem which relates to consumer acceptance of the product (4, 5, 7). Several practical methods for the manufacture of butter of acceptable and more uniform spreadability have been suggested such as temperature treatment of cream (7) and vacuum blending and mixing of butter (3). However, none of these practices have been accepted generally by the American butter industry. On the contrary, new developments like HTST pasteurization of cream and certain continuous manufacturing procedures appear to have resulted in a general decrease in the spreading character of butter (5).

The use of additives at some point of butter manufacture offers another approach to the solution of the problem of butter spreadability. The present paper deals with the effect of a wide variety of materials on the spreadability and hardness of butter manufactured under both laboratory and commercial conditions.

EXPERIMENTAL PROCEDURES

The study included (a) laboratory churnings in which the materials were added to either the cream or the butter, and (b) conventional and continuous plant-scale churnings with selected materials added to butter or butter oil. The butter manufacturing procedures were selected, in general, to represent common commercial practices rather than to provide butter of maximum spreadability. Spreadability, hardness, and organoleptic determinations were made on the butter at specific times.

Additives. Thirty-seven materials were investigated (Table 1), which included eight glycerides, six Tweens and Spans, four sta-

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TABLE 1

Types of materials investigated, concentrations used, and relative improvement on the spreading character of laboratory churned butter

Materials [a, b]	Concentration (% on fat basis)	Relative effectiveness on butter [c]
A. Glyceride preparations		
Myvacet 9-40 (B, C)	0.5–4.0	2 [d]
Myverol 18-00 (C)	0.5–3.0	0
Myverol 18-40 (B)	0.5–2.0	3
Myverol 18-71 (B)	0.5–2.0	3
Myverol 18-85 (B)	0.5–2.0	3
Mul-Crest (B, C)	1.0–3.0	1
Kraft emulsifier (C)	0.5–3.0	0
Atmos 300 (B, C)	0.5–3.0	2
B. Tweens and Spans		
Tween 40 (B, C)	0.5–3.0	2
Tween 60 (C)	0.5–3.0	1
Tween 80 (B)	3.0	0
Span 40 (B)	3.0	0
Span 60 (B)	3.0	0
Span 80 (B)	2.0–3.0	2
C. Stabilizers		
Instant Liquid ZZ-1Y (B)	1.0	0
Instant Liquid S-13 (B)	0.5–2.0	0
Extrumul (B)	0.5–2.0	0
Lecithin (liquid) (B, C)	0.5–2.0	2
D. Vegetable oils		
Rapeseed (B)	1.0	0
Sesame (B)	3.0	0
Corn (B)	1.0	0
E. Crystal inhibitors		
Air-blown Myverol 18-00 (B, C)	0.25–0.50	1
Air-blown cocoa butter (B, C)	0.25–0.50	1
Santopour B (B, C)	0.5	0
Santopour C (B, C)	0.5	0
F. Salts		
Disodium phosphate (C)	0.5–3.0	0
Sodium hexametaphosphate (C)	0.5–3.0	0
G. Enzymes		
Takamine protease (C)	0.05	0
Takamine clarase (C)	0.05–0.15	0
Takamine bromelin (C)	0.05	0
H. Miscellaneous		
Triton X-45 (detergent) (C)	0.5–1.0	1
Tergital penetrant (detergent) (C)	0.5–1.0	0
Propylene glycol (B)	0.5	0
Glycerol (B)	0.5	0
Aluminum stearate (B)	0.5–1.0	0
Skimmilk solids (B)	6.0	1
Buttermilk solids (B)	3.0–6.0	2

[a] Myvacet 9-40 (distilled acetylated monoglycerides) and Myverol compounds (distilled monoglycerides) manufactured by Distillation Products Industries, Rochester, New York.

Atmos 300 (liquid monoglycerides) and Tweens and Spans (Sorbitol derivatives of oleic and stearic acids) manufactured by Atlas Powder Company, Wilmington, Delaware.

Instant Liquid Emulsifiers and Extrumul (blends of monoglycerides and gums) manufactured by American Food Laboratories, Inc., Brooklyn, New York.

Santopour B and C (chlorinated hydrocarbons) manufactured by Monsanto Chemical Company, St. Louis, Missouri.

Takamine Enzymes manufactured by Takamine Laboratory, Clifton, New Jersey.

[b] (B)—tested in butter only; (C)—tested in cream only; (B, C)—tested in both butter and cream.

[c] Relative effectiveness in improving the spreadability and/or hardness of laboratory churned butter: 0—not effective (<10% improvement at the highest concentration); 1—slightly effective (10-20% improvement at the highest concentration); 2—effective (>20% improvement at the highest concentration); 3—very effective (>20% improvement at the 1% concentration or less).

[d] Effective only when added to cream.

bilizers, three vegetable oils, four crystalline inhibitors, two salts, three enzymes, and seven miscellaneous materials such as detergents, skimmilk solids, and buttermilk solids.

Laboratory churnings. Small-scale laboratory churnings were performed for the purpose of identifying those products which might be expected to be of maximum effectiveness under commercial conditions. The additives were incorporated (a) into the cream before pasteurization, or (b) into the butter during working. For the latter, it was found advantageous to add certain of the additives with a small quantity of a carrier material (propylene glycol, corn oil, or melted butter oil), to achieve adequate incorporation of the additive into the butter and to reduce the viscosity of the additive.

The laboratory procedure involved pasteurization of 1-gal lots of cream (155 F for 30 min), cooling to 40 F, and holding overnight. When enzymes were studied, they were permitted to react on the cream for 2.5 hr at 104 F before pasteurization. To achieve laboratory churning under standard conditions, six 1-gal glass churns were driven by a common line shaft. Churning was at 55 F in a constant temperature room. Under these conditions, churning was completed ordinarily within 60 to 90 min.

Following removal of the buttermilk, 1 gal of water (46 F-48 F) was added to the butter granules, held for 15 min, then drained as completely as possible. The butter granules were placed in a plastic bag which, in turn, was wrapped in heavy-duty canvas material for protection during working. The package of butter was placed in a 250-lb-capacity stainless steel Gosselin churn and working was accomplished by revolving the churn for 45 min. For each trial, one churning without additive served as the control.

Commercial churnings. The commercial phase of the study involved both conventional and continuous churnings and utilized only the addition of materials to butter.

For the conventional churnings, certain additives were mixed with butteroil before being distributed over the butter granules. In addition, to facilitate complete incorporation of some of these additives, it was necessary to permit the temperature of the butter to increase slowly to 70 F during working. This was accomplished by sprinkling the exterior of the churn with water at 73-75 F.

The cream used (300 lb of 33% fat) was processed and cooled as in the laboratory series, then was divided into 100-lb lots which were churned consecutively in a Gosselin churn at 53-55 F. The butter granules were washed once with water (45–48 F). The butter was adjusted to approximately 80% fat by addition of water and salt (2.5% on fat basis). Completeness of working was determined by Presto indicator paper. For each trial, the control was identical with the other lots, but did not contain the additive.

For the continuous churnings, conventional Cherry-Burrell continuous butter-making equipment (capacity—2,000 lb/hr) was used. The additives were incorporated into 20 gal of standardized butteroil at 100 F. This mixture was added to the butteroil surge tank and processed in the regular manner. To insure a representative sample, the first 80 lb of butter through the machine was discarded. The control consisted of the butter made from the butteroil without the additive.

Determination of spreadability and hardness. Spreadability and hardness determinations were made on all butters according to the procedure described previously (5) after two days of storage at 55 F and on plant-scale conventional and continuous made butter after additional storage for 30 days at 40 F and 90 days at −10 F. The latter butters were tempered at 55 F for 48 hr before testing. The instrument used, the Consistometer, is a carefully balanced pendulum with either a cutting blade (knife) or a wire attached to the lower end. It was demonstrated (5) that when the cutting devices are pulled through the butter by a constant-speed motor there is a direct relationship between the force exerted and the spreadability (by the knife) and hardness (by the wire) of the butter. The results are recorded in grams of resistance.

Organoleptic and chemical analyses. All plant-scale churnings were evaluated organoleptically by three experienced judges after storage for two and 14 days at 55 F, ten days at 70 F, and 180 days at −10 F. Additional analyses included pH of the serum and iodine and saponification values of the fat after storage of the butter for two days at 55 F, 30 days at 40 F, and 180 days at −10 F.

RESULTS

Laboratory churnings. The concentrations used and the comparative effectiveness of the various additives in laboratory-churned butter are listed in Table 1. In all, additions to cream and to butter involved 20 and 28 additives and 100 and 115 churnings, respectively. Seven additives were tested in both cream and butter. Generally, where comparisons were made, the use of an additive in butter proved more effective than the use in cream. One exception was Myvacet-90, which was quite effective at the 3 to 4% level when added to cream, but resulted in a decrease in spreadability and an increase in hardness when added to butter.

Based upon the arbitrary scale indicated in Table 1 by which the additives were rated according to a concentration/effectiveness relationship, nine of the additives were rated very effective to effective and 28 were rated slightly effective to ineffective. The effective concentrations and the percentage improvements in spreadability and hardness obtained with eight of the nine effective additives are indicated in Table 2. A direct comparison of effectiveness is not possible, since all of the compounds were not tested at the same level of concentration. However, the Myverol compounds 18-40, 18-71, 18-85 appeared to be the most effective, followed by Span 80, Atmos 300, Tween 40, liquid lecithin, and buttermilk solids. The improvements in spreadability and hardness were of equal magnitude with Atmos 300 and Span 80. In contrast, particularly effective results were obtained with the Myverol compounds for spreadability and with liquid lecithin for hardness. The butters made with six of the eight additives tended to be sticky when the additive concentrations were at the 2 to 3% level; Span 80 and buttermilk solids were the exceptions.

Seventeen combinations of two or three additives each were tested in 65 churnings. The most promising combinations and their effectiveness are listed in Table 3. The results re-

TABLE 2

Relative effectiveness of selected additives in improving the spreading quality of laboratory churned butter

Additive	Effective concentration	Improvement over control butter	
		Spreadability	Hardness
	(range, % on fat basis)	*(range, %)*	
Atmos 300	2.0–3.0	14–38	16–41
Lecithin (liquid)[a]	0.5–2.0	7–16	27–30
Tween 40	0.5–3.0	4–33	16–38
Span 80	2.0–3.0	25–39	23–30
Myverol 18-40[b]	0.5–2.0	16–41	8–29
Myverol 18-71[b]	0.5–2.0	22–60	11–46
Myverol 18-85[b]	0.5–2.0	22–45	15–34
Buttermilk solids	3.0–6.0	18–23	12–17

[a] Carrier material—25 ml melted butteroil.
[b] Carrier material—25 ml cornoil.

veal that a complimentary effect may be obtained by combining additives. For example, the Atmos 300–Tween 40 combination (0.5–0.5%) resulted in a 28% improvement in the spreadability of the butter; whereas, neither of these additives was effective at the 0.5% level when added individually. With some of the other combinations, the effect of the materials appeared to be merely additive. For example, the combination Myverol 18-71–Tween 40 (0.5–0.5%) resulted in an improvement in the spreadability of 25%, as compared to 22 and 4%, respectively, when the two additives were added singly in this concentration. The combinations of additives in relatively low concentrations which produced a marked improvement in spreadability produced no adverse effect on the body of the butter, i.e., no stickiness was observed.

Commercial conventional churnings. On the basis of the results of the laboratory churnings, 16 additives and combinations of additives were used in 30 plant-scale conventional churnings over a period of 1 yr. Butter oil served as the carrier material, since propylene glycol and corn oil had been found to cause off-flavors. Results for the most effective materials are presented (Table 4).

After two days of storage at 55 F the improvements in spreadability of the butter ranged from 10 to 44% for lecithin (0.5%) and lecithin-Myverol 18-71 (0.25–0.25%), respectively. The improvements in hardness ranged from 3 to 31% for lecithin-Span 80 (0.5–1.5%) and lecithin-Myverol 18-71 (0.25–0.25%), respectively. In general, the degree of improvement resulting from the various additions was similar to that observed in the laboratory churnings.

TABLE 3

Relative effectiveness of combinations of selected additives in improving the spreading quality of laboratory churned butter

Combinations of additives	Concentrations	Improvement over control butter	
		Spreadability	Hardness
	(% on fat basis)	*(%)*	
Atmos 300–Tween 40	0.5–0.5	28	19
Atmos 300–Lecithin	2.0–1.0	30	36
Atmos 300–Lecithin	1.5–1.5	31	32
Atmos 300–Lecithin	1.0–0.25	20	23
Atmos 300–Lecithin–Tween 40	0.5–0.25–1.0	24	19
Atmos 300–Lecithin–Tween 40	1.0–0.25–0.5	32	23
Atmos 300–Span 80	1.0–1.0	28	24
Atmos 300–Span 80–Lecithin	1.0–1.0–0.25	38	24
Myverol 18-71–Tween 40	0.25–0.25	16	12
Myverol 18-71–Tween 40	0.5–0.5	25	18

TABLE 4

Effect of selected additives and combinations of additives on the spreading quality of plant-scale conventional churned butter after different periods of storage

Additives	Concentrations	2 days at 55 F [a]		30 days at 40 F [a]		90 days at −10 F [a]	
		Spreadability	Hardness	Spreadability	Hardness	Spreadability	Hardness
	(% on fat basis)	*(% Improvement)*					
Lecithin [b]	0.5	10(480)	11(142)	7(532)	8(184)	9(540)	0(172)
Myverol 18-71 [b]	0.5	13(710)	25(225)	3(683)	9(220)	10(765)	20(200)
Tween 40	1.0	32(480)	17(190)	21(610)	12(180)	11(440)	0(125)
Span 80	3.0	25(567)	30(146)	17(792)	16(210)	16(665)	10(167)
Lecithin–Span 80	0.5–1.5	36(537)	3(90)	6(555)	14(110)	2(450)	15(130)
Lecithin–Myverol 18-71 [b]	0.25–0.25	44(567)	31(160)	31(570)	14(170)	25(485)	11(130)
Lecithin–Span 80–Atmos 300	0.25–1.0–1.0	39(680)	10(188)	6(710)	10(215)	2(635)	15(167)
Buttermilk solids	3.0	22(544)	14(155)	7(550)	11(180)	4(470)	−3(150)
Skimmilk solids	6.0	11(544)	14(155)	5(550)	3(180)	4(470)	13(150)

[a] Numbers in parentheses indicate the values for the control butters in grams.
[b] Carrier material—butteroil.

The beneficial effect of the additives in respect to spreadability tended to decrease when the butter was subjected to prolonged storage. In fact, although the storage effect on spreadability was somewhat variable, the improved spreadability produced in the fresh butter by most of the additives essentially disappeared during the storage period. Only the additive combination of lecithin-Myverol 18-71 (0.25–0.25%), which produced the most marked effect in the spreadability of butter after two days at 55 F, retained a considerable level of effectiveness after storage for 90 days at −10 F. The seasons of the year apparently had no effect upon the results obtained with the different additives in respect to effectiveness or stability during storage.

Commercial continuous churnings. The continuous churning studies utilized seven selected additives or combinations of additives for five summer and seven winter trials (Table 5). Hardness (wire) was the only criterion of consistency obtained for these butters, as their resistance to spreading (knife) usually was too great (approximately 1,600 g) to be measured reliably.

With respect to summer butter, none of the additives, with the exception of the combination Tween 40–Atmos 300 (0.25–0.5%) after 30 days of storage of the butter at 40 F, pro-

TABLE 5

Effect of selected additives and combinations of additives on the hardness of plant-scale continuous manufactured summer and winter butter after different periods of storage

Additives	Concentration	2 days at 55 F		30 days at 40 F		90 days at −10 F	
		Summer	Winter	Summer	Winter	Summer	Winter
	(% on fat basis)	*(% Improvement)*					
Lecithin	0.5	−6	35	8	−2	0	15
Myverol 18-71	1.0	−4	6	8	2	2	7
Myverol 18-71–Lecithin	0.25–0.25	−2	41	8	5	−3	10
Myverol 18-71–Tween 40	0.5 −0.25	−2	−5	8	−7	2	−14
Tween 40–Atmos 300	0.25–0.5	−2	23	16	3	6	10
Skimmilk solids [b]	6.0	....	5	....	0	....	0
Buttermilk solids [b]	3.0	....	−5	....	−2	....	0
Control butter *(g)*	0	423	528	497	520	567	565

[a] Hardness values only.
[b] Not tested in summer butter.

duced any effect on the hardness of the butter at any of the storage periods. For winter butter, three of the additives, lecithin (0.5%), Myverol 18-71–lecithin (0.25–0.25%), and Tween 40–Atmos 300 (0.25–0.5%), produced significant initial reduction in the hardness of the butter but, upon storage, the butter tended to increase in hardness.

Organoleptic and keeping quality of plant-scale churned butter. The flavor of the fresh butter was not affected by the majority of the additives at the 0.5 to 1% level. Above this concentration the butter was criticized for stale or cereal-like flavors. Tween 40 (0.5%) resulted in a bitter flavor and buttermilk and skimmilk solids (3 to 6%) resulted in sweet and powder-like flavors.

With respect to the flavor of the butter after various storage periods, most of the conventionally churned butter containing additives compared favorably with the control butter. The exception was butter, where difficulty with complete moisture incorporation was encountered because of the relatively high temperature of working. With such butter, the presence of additives resulted in the development of defects referred to as tallowy, stale, yeasty, cheesy, or ketone-like.

Continuous churned butters generally showed good keeping properties with the exception of the products containing added skimmilk and buttermilk solids, which deteriorated on storage. The excellent moisture distribution obtained by the continuous churning process probably contributed to the keeping quality of this butter.

The body and texture of the butter was not affected usually by the additives used at the 1% level or less. However, when the additives were used at higher concentrations, the butter tended to be gummy or sticky. Butter with 3 to 6% milk solids added tended to be brittle; particularly, when manufactured by the continuous procedure.

Chemical analyses. The chemical analyses of two-day-old control butters revealed the following over-all ranges: Iodine number, 29.8–35.5; Saponification number 227–231; and pH of the serum 6.5–7.3. These values were generally not affected by the additives and by storage, with the exception of the pH of the serum which tended to decrease in butters which developed cheesy and yeasty flavor defects during storage. No definite relationships were apparent between the iodine numbers and the spreadability and hardness of the conventionally churned control butters.

DISCUSSION

Results indicate clearly the distinct possibility that additives may be used to improve the spreading character and hardness of butter. At the same time, the findings reveal that the ideal additive is yet to be found. The materials used in this study, singly or in combination, admittedly were limited in number, but varied widely in chemical and physical characteristics and demonstrated widely different degrees of effectiveness. Undoubtedly, additional experimentation would establish other equally and perhaps more effective materials.

An additive must meet certain requirements if it is to be acceptable for commercial application. It must be effective in low concentration (1% perhaps should be considered the maximum level of addition), have no deleterious effect upon the flavor and keeping quality of the butter, be easily incorporated, and have a permanent effect. Several of the additives met the first two requirements, but failed in respect to the last two. Although ease of incorporation does not present a problem in continuous butter manufacture, it does for butter made by the conventional method. Unfortunately, some of the additives which were the most effective from the standpoint of favorable alterations in the spreadability and hardness of the butter, such as the Myverol preparations and lecithin, were among the most difficult materials to incorporate into the butter.

Where problems of incorporation of additives exist it appears necessary to use a carrier material. Perhaps butter oil should be given preference, primarily because other carrier materials such as vegetable oils may affect the flavor of the butter. Furthermore, in the final consideration, nonbutter-carrier materials would fall into the category of additives and, thus, if a maximum concentration for additives was to be established, the use of such carrier materials would force the butter manufacturer to reduce the concentration of the effective additive. The necessity for warming the butter during the conventional working process to facilitate complete incorporation of the additive may present a technical problem. Close temperature control during working is required, since abnormal increases in temperature of the butter may affect its spreadability adversely, particularly during the winter months (2).

The fourth requirement for a satisfactory additive, that of having a permanent effect on the butter, appears to be the most difficult to satisfy. The effectiveness of the majority of additives used in plant-scale churnings is probably related to the surface-active properties of the compounds. In addition, the additives may also affect the rate of setting of the butter. As indicated by the spreadability and hardness values for the control butters at the various storage periods, the majority of these butters were nearly completely set after two days at 55 F. Therefore, the greater effectiveness of the additives after two days of storage compared to that at later periods may have been a result of a delaying effect of the additives on the setting of the butter.

The results obtained focus attention upon the possibility of controlling the spreadability of butter by the use of crystal inhibitors or perhaps a combination of these and surface-active materials. The crystal inhibitors utilized were investigated as cream additives in laboratory churnings only, primarily because of toxicity considerations. Use of suitable food-acceptable crystal inhibitors may prove of great value in butter manufacture, particularly in continuous-made butter in which the spreading character is affected solely by fat crystallization (1).

Enzymatic alteration of the fat or the protein components of butter offers another possible approach. The present study was limited to lipases and proteases which were ineffective under the conditions of the experiment and did create certain flavor problems. Conceivably, enzymes may be found which can alter the chemical composition of milk fat (interesterification) which, in turn, would affect the crystal formation in the butter.

In continuous butter manufacture, differential crystallization of milk fat at controlled temperatures, and subsequent removal of the crystals of the high-melting point triglycerides by filtration or centifugation, would appear to be an effective approach towards improving the spreading quality of butter made from butteroil. However, its practicality appears questionable.

Perhaps the most attractive and practical approach towards manufacture of butter of desirable and uniform body characteristics would be application of vacuum blending before printing (3). Such a treatment offers a number of advantages. Among others, it results in destruction of the fat crystal framework which forms during setting. The destruction is permanent (6) and thus the addition of surface-active materials to the butter before blending might conceivably produce a product of superior spreadability. The main objections to the use of vacuum blending in this country have been cost, and the fact that the printing equipment could not handle blended butter. Cost is not a factor according to Australian studies (3). The recent increase in the number of soft butter printers in the industry would indicate that the equipment which can handle blended butter is becoming more common.

REFERENCES

(1) DEMAN, J. M., AND WOOD, F. W. Hardness of Butter. I. Influence of Season and Manufacturing Method. J. Dairy Sci., 41: 360. 1958.

(2) FISKER, A. N. Continued Experiments with the Tempering Method. Danish Govt. Research Sta. Bull. 75. 1952.

(3) GUNNIS, L. F. Vacuum Working: An Australian Practice in Butter Printing. Australian J. Dairy Technol., 13: 179. 1958.

(4) HUEBNER, V. R., AND THOMSEN, L. C. Spreadability and Hardness of Butter. II. Some Factors Affecting Spreadability and Hardness. J. Dairy Sci., 40: 834. 1957.

(5) KAPSALIS, J. G., BETSCHER, J. J., KRISTOFFERSEN, T., AND GOULD, I. A. Effect of Chemical Additives on the Spreading Quality of Butter. I. The Consistency of Butter as Determined by Mechanical and Consumer Panel Evaluation Methods. J. Dairy Sci., 43: 1560. 1960.

(6) SCHULZ, M. E., AND SYDOW, G. Die Anwendung des Brabender-Plastographe in Buttereiforschung. Milchwissenschaft, 12: 78. 1957.

(7) WILSTER, R. G. Smooth Spreading Butter. Milk Products J., 49 (7): 8. 1958.